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A sensor transponder and a procedure for measuring tyre contact lengths and wheel load

The present invention relates to a sensor transponder and a procedure for measuring tyre contact lengths and wheel load

A sensor transponder which is arranged in the vehicle tyre is already known from the German patent DE 44 02 136 C2, which comprises an acceleration sensor and a temperature sensor.

A sensor transponder with a pressure sensor is known from US 4,246,567.

The object of the invention is the simple and cost-effective calculation of the tyre contact area, since as the "effective" contact area between the tyre and the road, this significantly influences both the traction behaviour (the force transmission behaviour, braking behaviour) as well as the friction loss resulting from flexing. The object is furthermore to produce a suitable device for this purpose.

This object is attained by means of a sensor transponder with the features described in patent claim 1 and a related procedure with the features described in patent claim 8.

Advantageous further embodiments of the invention are described in the subordinate claims.

In the description below, the features and details of the invention will be described in greater detail using exemplary embodiments and with reference to the appended drawings. Here, the features and relationships described in the individual variants also apply in principle to all exemplary embodiments. In the drawings

Figure 1 shows a schematic view of an arrangement of a sensor transponder according to the invention with an acceleration sensor in one tyre

Figure 2 shows a diagram in which the progress of the centrifugal acceleration is shown with respect to the angle of revolution of the tyre

Figure 3 shows five further diagrams for evaluating the signals from the sensor transponder for an acceleration sensor with low-pass behaviour according to a first embodiment of the invention, and

Figure 4 shows five diagrams for evaluating the signals from the sensor transponder for an acceleration sensor with differentiating behaviour according to a second embodiment of the present invention

According to Fig. 1, a transponder or sensor transponder 1 for measuring a tyre contact length 6 is attached in accordance with the invention on the inner side of a tyre running surface 2. Using the transponder 1, data for one or more transmission and receiving antennae (not shown) which are arranged on the vehicle for example

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can be transmitted in a wireless manner. This data can then be transmitted, for example, to a superordinate central unit (not shown) as a digital value, or also as a signal (phase, frequency, amplitude or load modulation) which is modulated up to a HF carrier. Advantageously, but not necessarily, a comparison can be made in the central unit in particular between the individual data or signals and for example a correction of the tyre type, the temperature, the tyre pressure etc. and this can be forwarded to a superordinate system.

The transponder 1 comprises at least one acceleration sensor (not shown). The acceleration can be measured according to a capacitive (micromechanical, spring-mass areas), a piezoresistive (micromechanical, DMS seismic mass), ferroelectric (magnetic flow change), inductive (spring-magnet induction), electrodynamic (spring-electro magnet) or piezoelectric principle (material: in particular quartz, piezo ceramic or piezo foil; procedure: in particular bending, axial, torsion or shear strain).

With measuring principles which additionally have a generatory effect, such as the piezoelectric principle, the acceleration energy can also supply energy to the transponder 1 and load an electric buffer memory. In particular when sufficient energy is produced, the measurement signals can be transmitted to the receiving antenna or the central unit.

At least one acceleration sensor can also be used for triggering the signal transmission, since in order to reduce the load on a battery, a measurement is only important or advantageous while driving. In addition, the angle position of the sensor transponder 1 can be calculated, and this knowledge can be used to determine a suitable point in time for the optimum overlap of the corresponding transmission and receiving antenna(e).

According to Fig. 1, a countersink 4 of the tyre 2 is determined by the wheel load, the tyre type (dimensions, design, material etc.) and the pressure in the inner tyre. This countersink 4 results in a specific tyre contact length 6 on a road 5.

Due to its attachment on the inner side of the running surface 2, the transponder 1 is exposed to the progress 7 of the centrifugal acceleration a, represented in Fig. 2 as a complete revolution, i.e. an angle of rotation of between 0° and 360°. By contrast, were a sensor transponder purely theoretically mounted to a wheel rim 3, the continuous progress 8 of the centrifugal acceleration a, which is also represented in Fig. 2, would be effective.

The centrifugal acceleration a is calculated using the following known formula:

$$a = v^2 / r$$

This means that the centrifugal acceleration a with a constant radius r (were the transponder to be arranged on the wheel rim 3) and a constant velocity v is also constant (acceleration progress 8). In the area of the tyre contact length 6, due to the fact that it is mounted onto the inner side of the tyre running surface 2, no centrifugal acceleration 7 affects the sensor transponder 1, since here, the radius r runs counter to the infinite direction. When the sensor transponder 1 enters the area of the tyre contact length 6, the radius r initially decreases, leading here to acceleration peaks.

The same principle applies when the sensor transponder 1 exits the area of the tyre contact length 6.

For measuring purposes, the tyre contact length or tread length 6 can be calculated according to the invention by evaluating the centrifugal acceleration 7 of the sensor transponder 1 shown in Fig. 2. Here, initially at least one acceleration sensor is used to record the time or angle-dependent progress of the acceleration a, which is converted into a corresponding progression of stress. Using a threshold and gradient evaluation explained in relation to Figs. 3 and 4, the tyre contact length 6 which is relative to the full revolution and independent of the velocity can be calculated.

Knowledge of the tyre type can also be used to calculate to an adequate degree of accuracy the tyre contact area (tread). A further important variable, the wheel load, can then be calculated with the aid of the pressure in the inner tyre, the temperature and the tyre contact area.

By comparing these individual results (tyre contact length 6, wheel load, tyre contact area) for all tyres, i.e. all wheels, a conclusion can be advantageously reached regarding the tyre pressures relative to each other and/or which are absolutely incorrect. Furthermore, the wheel load and the tyre contact length 6 can be tested against prespecified limit values, and any excess of these values can be stored and, if necessary, displayed. In the further embodiment of the present invention, this information can for example be made available for a drive phase electronic system for optimising the engine-gear setting, or for a chassis electronic system for setting the damper-spring characteristics, and/or an electronic brake for adapting the brake coefficients.

The absolute (time-related) or relative (angle-related) tyre contact length 6 can for example be transmitted for this purpose to the superordinate central unit as a digital value, or as a signal (phase, frequency, amplitude or load modulation) which has been modulated up to the HF carrier.

The evaluation can be conducted, for example, in the manners described below with reference to Figs. 3 and 4. According to Fig. 3, with a DC-compatible (DC = direct current) acceleration sensor with low-pass behaviour, the centrifugal acceleration 10 is recorded with an acceleration sensor (output signal 11) and digitalised with the aid of a comparator threshold 12. Not shown in Fig. 3 are for example overlaid vertical accelerations which may arise as a result of the quality of the road 5 (Fig. 1).

The output signal 13 of the comparator controls an integrator 14 which can be realised in analogue (OP-AMP and/or RC elements) or digital (counter) technology, and the end tread-controlled value of which (marked by the bold arrows 16) is stored until the end of the period. With the positive flank in each case of the comparator output, a further integrator 15 is started, stopped and stored. Its output signal (marked by bold arrows 16) represents a value for the duration of revolution of the tyre 9. The quotient formation of the signals 14 and 15 or this stress ratio produce the relative tyre contact length 6 which is related to the tyre circumference, and which is thus independent of the velocity v or the rotational speed. Instead of the integrator 15, the rotational speed of the wheel can also be used in the calculation.

The signal evaluation of an alternative, non DC-compatible acceleration sensor with differentiating behaviour is represented in Fig. 4, whereby identical or similar components or signal procedures are assigned the same reference numerals as in Fig. 3. Here, the output signal 11 of the acceleration sensor is compared and evaluated in a comparative or similar manner against threshold values. In particular, the quotient or ratio formation of the signals 14 and 15 is achieved, as a result of which the tyre contact length 6 can be calculated independently of the velocity v.

These two procedures according to the invention directly calculate the tyre contact length 6, but knowledge of the tyre type can also be used to calculate to an adequate degree of accuracy the tyre contact area (tread). A further important variable, the wheel load, can be calculated with the aid of the pressure in the inner tyre, the temperature and the tyre contact area. With the aid of the sensor transponder 1 according to the invention, and in particular its particular arrangement, the relevant data can be obtained. Therefore according to the invention, in an advantageous manner, the tyre contact area and the wheel load can be calculated from the tyre contact length 6 via its relationship to or dependence on the pressure in the inner tyre, the rotational speed of the wheel and/or the type of tyre used.

In a preferred, full construction stage, the sensor transponder 1 preferably also comprises, alongside at least one acceleration sensor, sensors for temperature and pressure and a memory for tyre-specific parameters.

The essential features and advantageous further embodiments of the sensor transponder 1 according to the invention will again be described below. The transponder 1 is mounted according to the invention on the inner side of the running surface 2 of the tyre 9. It comprises at least one acceleration sensor for the measurement of the tyre contact length 6 described above. In addition, a memory for the tyre-specific parameters for calculating the tyre contact area can be integrated on the sensor transponder 1. Furthermore, the transponder 1 comprises as an option a pressure sensor for monitoring the tyre pressure and calculating the wheel load. In addition, a temperature sensor for measuring the temperature and correcting the measurement values can be fitted on the sensor transponder.

List of reference numerals:

1	Sensor transponder
2	Tyre running surface
3	Wheel rim
4	Countersink
5	Road
6	Tyre contact length
7	Centrifugal acceleration
8	Centrifugal acceleration
9	Tyres
10	Centrifugal acceleration
11	Output signal, acceleration sensor
12	Comparator threshold
13	Output signal, comparator
14	Integrator
15	Integrator
16	End value or output signal (bold arrows)

a	Centrifugal acceleration
r	Radius
v	Velocity